Feb. 21, 1967 I. G. NADEL 3,304,867

SOLID PROPELLANTS IN TEXTILE FORM

Filed Feb. 10, 1965

Fig. 1.

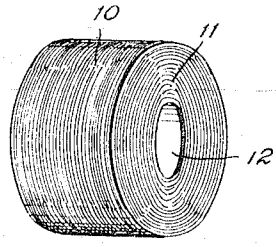


Fig. 2.

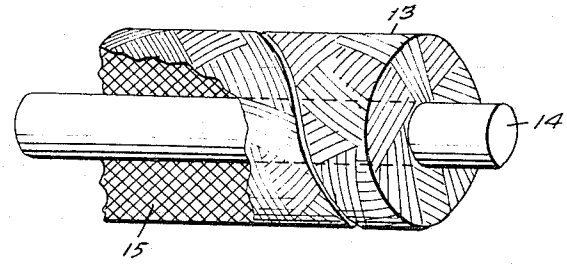


Fig. 3.

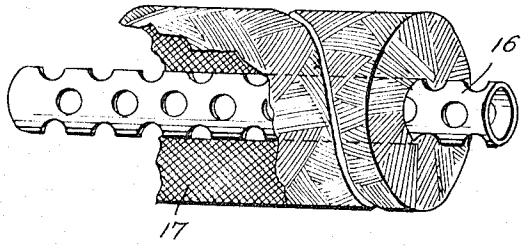


Fig. 4.

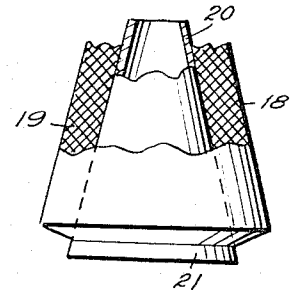


Fig. 5.

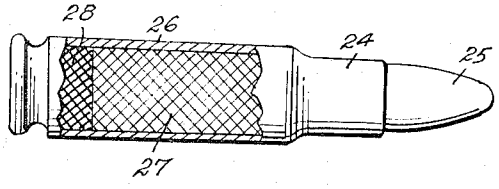


Fig. 7.

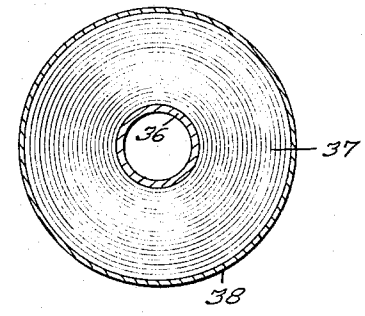
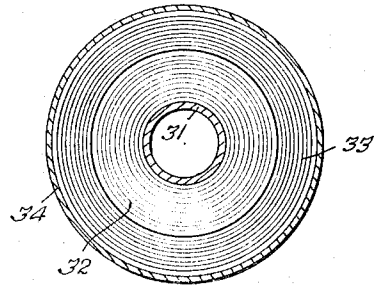


Fig. 6.



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SOLID PROPELLANTS IN TEXTILE FORM

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15 Claims. (Cl. 102—98)

The invention described herein may be manufactured and used by or for the Government for governmental purposes, without the payment to me of any royalty thereon.

This application is a continuation-in-part of copending application Serial No. 180,929, filed March 12, 1962, now abandoned, which was in turn a continuation of patent application Serial No. 697,296, filed November 18, 1957, and now abandoned.

This invention relates to improvements in propellant charges and more particularly concerns continuous filamentary strands which can be spun from propellant compositions and formed into highly combustible, textile-type packages.

Prior to the discovery of the present invention, propellant charges for use in cartridges, artillery ammunition, mortars, rockets and the like have been produced from a plastic colloidal mass of cellulose nitrate, said mass including various other constituents of the charge dissolved or suspended therein. These charges were commonly prepared in a variety of forms such as, flakes, sheets, pellets, strips, cards or rods and loaded into conventional cartridge cases and like containers. Propellant charges have also been obtained by extruding the plastic composition through dies to provide a sheet, ribbon, cord or perforated spaghetti-like strings or strands which were subsequently fed to cutting machines and reduced to segments, sections, wafers or grains of desired dimensions.

The above described method and propellant grains produced thereby possessed several undesirable characteristics. Thus, uniformity in the grain size was difficult to achieve because the extruded material of the prior art possessed considerable dimension, and solvent removal from the extruded form was undesirably lengthy and difficult to control with any degree of accuracy, resulting in uneven shinkage in the dried product. Even more important, the fibers were considerably brittle and of inferior mechanical strength.

Proper ballistic performance is dependent upon the propellant remaining as an integral unit during handling and combustion of the charge, since highly fragmentary grains expose a greater burning surface than that considered desirable with the result that erratic ballistic performance may be obtained. Considerable difficulty is also encountered in providing for uniform distribution and optimum packing of such propellant forms as staple fiber, sheet and woven material, into cartridge cases, projectile chambers, etc. that will possess after loading sufficient mechanical strength as to eliminate fragmentation or fracture of the propellant.

The above recited difficulties encountered in formulating propellant charges with determinable and reproducible ballistic characteristics serve to emphasize the importance to be accorded the development of novel propellant grains having ballistic properties of considerable uniformity and subject to precision control by the manufacturer or designer. The present development of a highly efficient textile-like propellant relates to novel structural arrangements which are such as to harness and direct the explosive power by proper control of burning.

Accordingly, a primary object of this invention is the development of a propellant charge, the burning rate of which is subject to precision control with or without variations in the chemical composition of the charge.

Another object of the invention is to provide a propellant structure capable of being used without cartridge

cases of either the combustible or conventional metal types.

A further object of the invention is the development of solid propellants which are superior to prior art extruded material in that they offer greater resistance to fracture and fragmentation.

A further object relates to the formation of solid propellant packages formed of textile-type windings spun from propellant compositions.

A further object relates to the formation of a solid propellant having a considerably increased density above that capable of being achieved by loading conventional granulated propellant.

A still further object is the elimination of time-consuming steps of formulating powder grains and blending them in the production of granular propellants.

Other objects and advantages of the invention will become obvious to those skilled in the propellant art as the invention is described hereinafter.

According to the present invention a solid propellant is provided in the form of a textile-type filamentary material capable of being twisted, plied or otherwise wound into "yarn" packages of any desired shape and size. The solid propellant comprises continuous filament formed into a unitary structure by grouping the filaments into strands, yarns, threads, tows and the like, and winding the same into cylindrical, spherical, conical and other desired shapes for use as propellant grains. Thus filament-winding produces yarn packages; the filament wound to a prescribed pattern and thickness to provide a novel solid propellant with varied ballistic properties.

As described in my parent application Serial No. 697,296, filed November 18, 1957, numerous propellant compositions of the nitrocellulose type may be formed into a spinning dope by solution in any suitable volatile solvent such as acetone. This spinning dope is then extruded under pressure through spinnerettes similar to those normally employed in the manufacture of synthetic textile fibers and solidified into continuous filaments by either the wet or dry spinning methods conventionally used or in spinning viscose, cellulose acetate filaments. The resulting filaments, which remain flexible and tenuous, are then arranged into multifilament strands, tows or yarns and wound on solid or hollow cores and also in the form of hollow, wound bodies of any desired configuration, size and density according to the specific ballistic properties desired.

For purposes of this invention, terms such as "filamentary material" and "textile-type material" are defined as including any materials composed of, or containing structural units having dimensions, strength, flexibility and other characteristics sufficiently similar to conventional textile fibers to permit their processing on conventional textile machinery to form textile-like strands, yarns, threads, fabrics and filament structures.

The term "strand" as used in the specification designates any textile structure characterized with extreme length as compared to its width or diameter, whether composed of a continuous monofilament or multifilaments and includes yarns, threads, tows, or loose bundles of fiber lengths.

The solid propellant of this invention, including methods of producing same will now be described in detail with reference to the accompanying drawing in which:

FIGURE 1 illustrates a propellant yarn package formed with a center air space, the package being a continuous winding of nitrocellulose composition;

FIGURE 2 illustrates a similar propellant yarn package wound in an open-wind pattern on a solid cylindrical core;

FIGURE 3 illustrates a similar package having a close-wind pattern and contained on a perforated core;

FIGURE 4 is a view partly in cross section of a conically wound, hollow propellant package;

FIGURE 5 illustrates one method of utilizing the textile-type yarn package of the invention;

FIGURE 6 illustrates one embodiment of an "inhibited" solid propellant yarn package; and

FIGURE 7 illustrates another embodiment of an "inhibted type" solid propellant yarn package.

In the practice of this invention, any substantially noncrystalline, propellant composition which is capable of forming a flexible, tenuous filament on extrusion through a spinnerette may be employed. In general, it has been found that compositions containing large proportions of nitrocellulose are more adaptable for extrusion and form suitable filamentary material for the desired end use. In addition to nitrocellulose, the present compositions may contain stabilizers, plasticizers, coolants and other modifying agents customarily used in blending modern propellants. The compositions thus formed are dissolved in any compatible, volatile solvent, such as acetone, and extruded under pressure through a spinnerette having a multiplicity of orifices of a size suitable to provide filaments of the desired denier. The filaments may be spun by either the wet or the dry method. In the wet method, the composition forced through the spinnerette passes directly into and through an aqueous bath to solidify the filamentary material and remove the solvent present in the composition. The aqueous bath may be simply water or a dilute solution of such salts as are customarily employed in coagulating synthetic filaments in the manner of viscose rayon and the like. In the dry spinning method, the filaments leaving the spinnerette pass through a stream of warm, humid air for a distance sufficient to solidify the spinning composition and remove the bulk of the acetone or other solvent.

During the period of solidification and formation, tension is exerted on the filaments sufficient to stretch them to effect molecular orientation and thus increase the tensile strength of the filaments and decrease their diameter. At this point, the bundle of filaments issuing from a spinnerette is usually given a slight twist sufficient to hold it together in the form of a unitary tow, bundle or strand. For this purpose, ½ to 3 turns per inch are usually sufficient. The strand formed in this manner may then be wound on any spool, bobbin or core by means of conventional textile winding machines. The wound product may be conveniently stored for further processing or utilized directly as a spun package of propellant charge. Filaments prepared according to the above method may be formed with any desired denier. However, for practical purposes it has been found that filaments having deniers ranging from about 3.75 to 8.0 are to be preferred. Any desired number of filaments may be extruded simultaneously depending on the number of orifices in the spinnerette. The number of orifices may run as high as 200 or more. In the development of the present invention, spinnerettes with 40 and 50 orifices were employed. Thus the bundle of filaments produced from one spinnerette may range in size from 150/40 (40 filaments having an individual denier of 3.75 giving a total strand denier of 150) to 400/50 (50 filaments having an individual denier of 8.0 giving a total strand denier of 400).

Depending upon the properties desired in the final product, the tow or bundle of filaments described above may be further processed to impart a higher degree of twist therein. The resulting yarn is then wound in a predetermined pattern on any suitable type core element, as will be described in greater detail with reference to specific embodiments to provide a wound package of any desired size, configuration and density. The filaments of the yarn package may be bonded together by suitable bonding compositions, and the packages may be at least partially encased with a layer of a combustible, nonpropellant material formed of a plurality of windings.

FIGURE 1 of the drawing shows a yarn package **10** comprising a multiplicity of windings **11** of a solid propellant wound into a cylindrical configuration and having a hollow core **12**. The yarn package may be formed of any desired winding pattern such as circular or helical windings with any desired spacing between the strands. The pattern may vary from one in which the starting points of consecutive windings are separated only by a strand width to one which is so complex as to appear completely random. The precision with which the winding pattern is maintained will dictate the quality and properties of the propellant yarn package.

Propellants are utilized under conditions whereby they are ignited and burned. The form of the propellant as well as its characteristic burning rate determines the time required for complete burning or relative "quickness" values of propellants. When a propellant yarn in accordance with the present invention is wound closely and tightly to form a dense package, the burning time is different than a more loosely wound package. Thus, by controlling the density and physical form of the propellant charge, the ballistic effect of the propellant is determined and kept near optimum values.

As further explanation of the manner in which strands of a solid propellant can be utilized effectively to provide spun propellant charges, there is shown in FIG. 2 a yarn package **13** having a cylindrical configuration as the package of FIG. 1, but in the present embodiment the yarn is wound on a solid core **14**. The core may be made of a material such as metal, plastic, or wood. Helical windings **15** are depicted as wound on the core in a relatively open structure with a considerable amount of air spacing among the strands. The helical winding pattern of high angles shown in the drawing is merely intended to illustrate a further variation which may be achieved in the spun propellant charge of the present invention. The density or porosity of the package may be varied at will be selecting the proper pattern of winding the yarn on the core, by varying the denier and degree of twist in the strand and also by adjusting the spacing between adjacent windings in said package. Closely-wound strands will result in a tight, dense package whereas strands wound with a certain uniform spacing between adjacent windings will result in a loose, porous package.

FIGURE 3 illustrates a package similar to that of the previous embodiment, however in this case the strand is wound on a perforated core **16** of any selected material; the perforated design thereof providing additional means for varying the burning characteristics of the charge. Also the strand is depicted as closely wound giving a denser package that provides thereby a burning time different from that of the open windings of the embodiment shown in FIG. 2.

A further embodiment of the present propellant structure is illustrated in FIGURE 4 which shows a conical yarn package **18** wound on a conical cardboard cone **20**. The propellant strand **19** may be wound on the cone with progressively changing spacings to provide varying densities of the yarn within a single package. The conical core on which the propellant yarn is wound may be removed if desired or the package may be wound without a core on a conical mandrel by conventional textile machinery.

A propellant grain or yarn package with desirable ballistic properties may be fabricated by varying (1) the length of strand wound on the package, (2) the length of the package, (3) the inner and outer diameter of the package and (4) the type of propellant strand used in said package. The propellant strand forming the package may comprise a loose, relatively untwisted bundle or tow of continuous monofilaments, or it may comprise a highly twisted bundle of filaments. Additionally, plied yarn may be employed, each ply being of the same type filaments or of a different denier, twist play or chemical composition. The yarn may be blended of a plurality of different types of propellant filaments spun from different propellant compositions, which may be "diluted" with varying amounts of

a non-propellant yarn, such as cellulose acetate, regenerated cellulose and the like.

The following specific examples are given by way of illustration of solid propellant compositions which may form the yarn packages of this invention. In these examples as elsewhere throughout the specification, all parts and percentages are given in terms of weight.

EXAMPLE I

A quantity of continuous filament yarn was spun using the following propellant composition:

	Percent
Nitrocellulose (12.6% N.)	99
Diphenylamine	1

One part of the above composition was dissolved in four parts by weight of acetone. The solution was filtered through cotton flannel to free it of all undissolved gels and other insoluble impurities. The resulting spinning dope or lacquer was extruded under pressure through a spinnerette having 40 orifices of a size sufficient to result in individual filaments having a denier of 3.75. On leaving the spinnerette, the bundle of 40 filaments were passed through a warm, humid atmosphere for a distance sufficient to result in the substantially complete removal of acetone solvent from the filaments. During the drying stage the filaments were stretched slightly to effect molecular orientation and thus increase the tensile strength of the individual filaments. An S-twist of approximately one-half turn per inch was imparted to the bundle of filaments and the bundle was then wound on a storage reel. Subsequently, the yarn was given a further S-twist of about 10 turns per inch and then rewound on a cylindrical cardboard core 6½ inches long and ¾-inch in diameter to form a tightly-wound, cylindrical yarn of 2 inches in diameter and a length of 6 inches. The resulting yarn package was used as a single grain of propellant in place of the customary cartridge case containing a large number of the usual small perforated grains.

It is to be emphasized that several features of the above package or grain afford variations and advantages to the ballistic properties of the final grain. The novel form of wound strands of propellant affords means of attaining precision control over the burning rate and other properties of the grain. The difficulty previously encountered in fabricating multiperforated grains having exceptionally thin webs are readily overcome by the present multifilament stands. The size of orifices may be varied to extrude finer or heavier denier filaments, the preferred range of filament being from 3.75 to 8.0 denier per filament but actually being limited only by mechanical difficulties in handling extremely fine or coarse filaments. The number of filaments may also be varied, thus providing larger or smaller bundles or strands. Bundles of filaments may also be combined before twisting to form tows having several hundred monofilaments therein.

Furthermore, the amount of twist imparted to the strand may be varied according to the precise ballistic properties desired. Two identical twisted yarns or strands may be plied together or a plied yarn may be formed wherein one of the plies is formed in one manner according to the invention, while the other ply may have the same chemical composition but different denier filaments, with varying number of filaments, twists, etc. Also, each ply may consist of filaments of a different propellant composition or, where dilution is desired, a propellant yarn may be plied with a non-propellant yarn, for example, cellulose, or a synthetic fibrous yarn.

Variations may also be achieved in the density of the yarn by winding the strand with an indexed interval between adjacent windings and by employing various types of winding patterns to form open or close-wound packages. Grain density may also be increased by lightly wetting the yarn with a nitrocellulose solvent, such as acetone just prior to winding. In this manner the surface of the yarn is softened or gelatinized slightly and on being wound on the package is cemented firmly to adjacent windings of the yarn. Various bonding agents, such as the epoxy resins, and various plasticizers, such as triacetin and dibutylphthalate, may be applied to the yarn during processing.

The results of various tests measuring sensitivity, accelerated stability and firing have shown that propellant yarns and propellant packages of the present invention are stable, not unduly sensitive and which may be handled with normal precautions accorded conventional propellants.

EXAMPLE II

A propellant powder having the following composition:

	Percent
Nitrocellulose (13.5% N)	79.90
Nitroglycerin	19.50
Ethyl Centralite	0.60

was dissolved in acetone to obtain a spinning dope containing 78% acetone and 22% nonvolatile components. After filtering through cotton flannel, the dope was extruded under pressure through a spinnerette having 50 orifices of a size sufficient to provide filaments having a denier of 8.0. After processing by the dry method of spinning as described in Example I, the bundle of filaments was given a Z-twist of approximately 15 turns per inch and plied with a strand produced according to Example I having an S-twist of 10 turns per inch. The final two-ply yarn was then wound on a solid cylindrical core in a helical winding pattern, shown schematically in FIG. 2.

EXAMPLE III

	Percent
Nitrocellulose (12.6% N)	85
Dinitrotoluene	10
Dibutylphthalate	5
Diphenylamine (added to above mixture)	1

The above propellant composition was dissolved in acetone to form a spinning dope having a concentration of 26.5%±0.2% nonvolatile material. The viscosity of the dope was 2250 at 25° C. Suspended particles in the filtered material did not exceed 5 microns in size. A bundle of 40 filaments having a filament denier of 3.75 and total denier of 150 was spun by the dry spinning method previously described. Microscopic examination of the filaments showed substantially round cross-sections. No evidence of crystalline or solid foreign matter was apparent in the filaments. The yarn was water-rinsed to reduce residual solvent. The water content of the yarn was reduced to approximately 25%, and the yarn was wound on a removable mandrel in relatively close spaced circular windings, as shown in FIG. 1.

Any known nitrocellulose propellant whether of the single or double base type may be formed into filaments by the above described methods, except for those compositions having a high crystalline content. For all practical purposes, propellant compositions having a crystalline content greater than about 20% have been found to form filaments too fragile to be of use in the manner intended. Other examples of suitable propellant compositions are as follows:

EXAMPLE IV

	Percent
Nitrocellulose (13.15% N)	98
Diphenylamine	2

EXAMPLE V

Nitrocellulose (13.15% N)	98
Potassium sulfate	2
Diphenylamine (added to above mixture)	1

As may be seen from the above compositions, filaments may be spun from any nitrocellulose type propellant either of the single or double base type. Thus, the explosive ingredient may consist essentially of nitrocellu-

lose or a varying amount of nitrocellulose may be replaced by nitroglycerin, dinitrotoluene, or the like. In addition to the explosive ingredient or ingredients, the propellant composition should contain a stabilizer, such as diphenylamine, methyl centralite, ethyl centralite, or 2-nitro-diphenylamine. Use of a plasticizer such as dibutylphthalate or triacetin is found advantageous in many instances. Compounds having both explosive and plasticizing properties, such as nitroglycerin, TEGN (triethylene glycol dinitrate) and DEGN (diethylene glycol dinitrate) may also be used to advantage.

Nitrocellulose of any degree of nitration may be employed. However, nitrocellulose having a nitrogen content of from about 12.6 to 13.25 percent by weight has been found to be most satisfactory.

FIG. 5 illustrates one of numerous ways in which the solid propellant of this invention may be utilized in conventional ammunition. Thus, a cartridge designated generally as 24 comprises a bullet 25 attached to a cartridge shell 26 containing a single grain 27 of propellant in the form of a yarn package of appropriate size. The priming material 28 located at the end of the cartridge case may also be utilized in the form of a filament or strand winding within the shell.

If desired further modification and variation of the burning rate and other ballistic properties of the propellant grain may be made by forming concentric layers of different propellant strands about the core. Thus, for example, a yarn having the composition of Example I may be wound a number of times about the core to give a propellant layer of any desired thickness. This propellant layer may then be followed by a plurality of windings of a yarn of a different composition, denier, twist, ply, etc., to form a second concentric layer. In this manner a package is formed in which concentric layers of propellant yarns of different chemical or physical properties may be built up to form a grain having the desired ballistic properties.

The grains or yarn packages of the invention formed as described above may be inhibited to provide additional structures. Thus, in the embodiment shown in FIG. 6, the inhibited grain comprises a core 31, the propellant winding 32 formed of a multiplicity of windings of propellant yarn, a layer of cellulose acetate yarn 33 of any desired thickness, but preferably of the order of 1/16 to 1/4-inch, and an external substantially continuous coating 34 formed by applying cellulose acetate butyrate lacquer to the surface of yarn 33. A suitable lacquer for surface application consists essentially of a 5% solution of 1/2-second cellulose acetate-butyrate in equal volumes of methanol-toluene solvent. A layer of this lacquer applied to the surface of yarn 33 by brushing, satisfactorily inhibits the propellant without attacking either the acetate or nitrate fibers and at the same time imparts water repellency to the grain.

Another embodiment illustrating further means of inhibiting a propellant yarn is demonstrated in FIG. 7 wherein a solid propellant with core member 36 and strand winding 37 is wrapped with a sheet of cellulose acetate 38 and bonded thereto by means of acetone or other suitable bonding means.

Still another method of inhibiting consists of applying acetone directly to the external surface of the yarn package to soften the external windings of propellant yarn and form a substantially continuous film of propellant composition around the yarn package.

Although the propellant composition is normally extruded in the form of filaments having a round cross-section, the extrusion process may also be adapted in the formation of propellant filaments having elliptical, cruciform, square or other cross-sectional forms.

From the above detailed disclosure and examples of my invention, it will be apparent to those skilled in the art that I have now discovered a novel form of propellant charge which is ideally suited for use as solid propellants in artillery, small arms, mortar and recoilless ammunition. The new propellant charge is capable of adaptation to a wide variety of ballistic properties by variation of filament and denier, number of filaments per yarn, degree of twist therein, chemical composition of the filaments thereof, the porosity of the propellant package, the physical dimensions of the package and the degree of openness or closeness of the wind. The novel propellant charge presents numerous advantages over previous propellant forms. For example, more accurate control of ballistic properties of the charge; its use without the need for conventional cartridge cases and like containers; its increased density over granular propellants; its improved mechanical strength, particularly at low temperatures and its chemical uniformity over other extruded forms. The comparative ease in manufacturing continuous filament and yarn package on standard textile equipment enables the textile industry to provide immense aid in time of emergency with rapid conversion and know-how in fabricating the present solid propellant yarn.

In the foregoing description of the invention I have disclosed preferred embodiments thereof. However, it is not intended that the invention be limited to the specific examples set forth above, as it will be apparent to those skilled in the art that the chemical composition and physical characteristics of the novel propellant may be varied over a wide range without departing from the spirit and scope of the invention, any limitation thereof being set by the appended claims.

Having thus described the invention, what is claimed is:

1. A spun propellant charge comprising a continuous filament of nitrocellulose composition, a central core, said filament being wound as a plurality of layers on said central core.

2. A propellant in accordance with claim 1 in which said filament has a denier between 3.75 and 8.0.

3. A spun propellant charge comprising a plurality of continuous filaments of nitrocellulose composition twisted to form a strand, a central core, said strand being wound as a plurality of layers on said central core.

4. A propellant in accordance with claim 3 wherein said strands are bonded together with a combustible, non-propellant material.

5. A propellant in accordance with claim 3 in which said layers are enclosed in a combustible, non-propellant material formed as a plurality of filamentary windings.

6. A spun propellant charge as in claim 3 in which said core is perforated the length thereof.

7. A propellant in accordance with claim 6 wherein said layers are enclosed in combustible, non-propellant material.

8. A spun propellant charge as in claim 3 in which said core is formed of a solid material selected from the group consisting of metal, plastic and wood.

9. A spun propellant charge in accordance with claim 3 in which said strand includes other filaments consisting essentially of a non-propellant composition to vary the burning rate of the charge.

10. A spun propellant charge comprising a plurality of continuous filaments, a central core, said filaments being wound as a plurality of layers on said central core, said filaments consisting essentially of a nitrocellulose composition having a nitrogen content of from about 12.6 to 13.25 percent.

11. A spun propellant charge comprising a plurality of continuous strands of filamentary nitrocellulose composition, said strands being plied together to form a plied yarn, a central core, said yarn being wound as a plurality of layers on said central core.

12. A spun propellant charge comprising a plurality of continuous filaments wound as a plurality of layers on a central core, said filament consisting essentially by weight of about 85 percent cellulose nitrate having a nitrogen content of from about 12.6 to 13.25 percent, of about 9

percent dinitrotoluene, of about 5 percent dibutylphthalate and of about 1 percent diphenylamine.

13. A spun propellant charge comprising a plurality of continuous filaments wound as a plurality of layers on a central core, said filament consisting essentially by weight of about 79.9 percent cellulose nitrate having a nitrogen content of at least 12.6 percent, of about 19.5 percent nitroglycerin and of about 0.6 percent ethyl centralite.

14. A spun propellant charge comprising a plurality of continuous filaments wound as a plurality of layers on a central core, said filaments consisting essentially of a nitrocellulose composition having a nitrogen content of from about 12.6 to 13.25 percent and including in said composition of from 0.5 to 2.5 percent by weight of a stabilizer.

15. A spun propellant charge comprising a plurality of continuous filaments wound as a plurality of layers on a central core, said filaments consisting essentially of a nitrocellulose composition having a nitrogen content of from about 12.6 to 13.25 percent and including in said composition approximately 1 percent diphenylamine by weight.

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